PROGRESS REPORT NO. 2

on

SEDIMENT MANAGEMENT FOR SOUTHERN CALIFORNIA MOUNTAINS, COASTAL PLAINS AND SHORELINE

A Joint Project of the

Environmental Quality Laboratory
California Institute of Technology

and

Shore Processes Laboratory
Scripps Institution of Oceanography

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INTRODUCTION

During FY77, with financial support from Los Angeles County, U. S. Geological Survey, Orange County, U. S. Army Corps of Engineers, and discretionary funding provided by a grant from the Ford Foundation, substantial progress was made at EQL and SPL in achieving the objectives of the initial Planning and Assessment Phase of the CIT/SIO Sediment Management Project. The current timetable for completion of this phase is June 1978.

This report briefly describes the project status including general administration, special activities, and technical work.

ADMINISTRATION

During the past year there has been a continuing effort to establish and maintain close liaison with appropriate local, state and federal agencies in an attempt to increase the technical involvement of these agencies, and to obtain financial support from all agencies that will derive substantial benefits from the CIT/SIO study.

In late 1976 the Corps of Engineers approved funding for the CIT/SIO project ($\$50^k$/yr: two years). First-year funding from COE was forwarded in May 1977.

During March a letter of agreement for technical assistance was signed with the U. S. Forest Service. Under the terms of this agreement a Masters level research hydrologist has been assigned to work 2 days/wk at Caltech on project sub-studies of special importance to the Forest Service. Initially the hydrologist (Wade Wells) is working on the effect of fires on sediment yield from upland watersheds. Wade is a full time staff member of the San Dimas Experimental Forest Research Work Unit in Glendora.

A new commitment of project support has also been indicated by the Department of Navigation & Ocean Development in the State Resources Agency. This support is scheduled to start at the beginning of FY78.

In June 1977 a meeting was held with Ventura County to begin negotiations for transferring funds to Caltech in support of the CIT/SIO sediment management project. It is anticipated tht this funding will be forwarded to EQL during the first quarter of FY78.

With these new and the continuing financial resources anticipated for the coming year the scale of project effort can be increased somewhat. However, additional commitments by other agencies will be necessary to enable the full-scale effort planned (see Appendix A).

We are currently conducting negotiations for additional financial support with Sea Grant, U. S. Forest Service, and the County of San Diego.

SPECIAL ACTIVITIES

During 1976 two special project activities were undertaken--a two-day workshop, and the introduction of a newsletter to report on the CIT/SIO study and other issues pertaining to regional sediment management. Approximately 200 people attended the workshop including representatives from 25 federal, state and local government agencies, 11 universities, public utilities, engineering and consulting firms, and the general public (see Appendix B for complete list of attendees). This workshop helped to clarify research questions pertaining to regional sediment management and to promote a cooperative research effort among instutions and agencies. The general conclusion of the workshop might be stated as follows: the large population, high level of development throughout the coastal region of southern California, and diverse and intense use of local resources for industry and recreation (some 50 million user-days of shoreline recreation and 10-14 million user-days of mountain and national forest recreation per year) underline the importance of understanding the natural sediment balance and the effects man has imposed on it. More thorough analyses of inter-regional management strategies are needed to help ensure that we do not contradict our own efforts in attempting to solve existing sedimentation problems, and that our actions do not produce undesirable results that may be very costly or impossible to correct in the future.

The newsletter was initiated to build upon and continue workshop objectives, i.e. provide a vehicle for a continuing informal exchange of ideas and information among managers, engineers, and scientists involved in sedimentation problems in southern California, and to disseminate information on the CIT/SIO project. This newsletter will be published periodically as necessary to meet these objectives. More than 1000 copies of the first newsletter, printed in November 1976 were distributed to managers, engineers, academic people, county, state and federal political representatives, and other interested parties. The second newsletter will be published during July.

TECHNICAL WORK

Technical work at Caltech during the first 1-1/2 years has included data compilation: tabular, computerized data files, and mapping. Preliminary data analysis has been directed toward obtaining first-order estimates of the mean annual values of sediment movements from upland areas and shoreline sediment deliveries under present and recent past conditions. Secondary studies have been focused on upland watershed erosion, natural versus controlled sediment deliveries to the shoreline between 1925 and 1975 by the nine major rivers in the study area (see map in Fig. 1), and analyses of changes in the shoreline and beaches. These work elements are described in the following sections.

I. Data Compilation

During 1976 and 1977 the following data have been compiled:

1. Streamflow data: daily mean and annual peak flows for several hundred large and small streams throughout the study area. A master list of all available streamflow records has been obtained from the California Department of Water Resources and has been entered onto magnetic tape for ready computer access. The list encompasses 852 stations in the study area at which streamflow data were collected. Some 450 of these stations have been operated by the U. S. Geological Survey, and the master computer files of the USGS have been accessed to transfer useful data to the Caltech files.

2. Sediment-transport data: daily mean discharges and individual sample data for both suspended-sediment and bedload transport. These USGS data are derived from 32 stations in the study area, of which
   a) 20 stations have from 1 to 9 years of continuous records;
   b) 19 stations, primarily on upland drainages in the Santa Clara River basin, have intermittent records;
   c) 2 stations (the Los Angeles and San Gabriel Rivers near their mouths) were established in late 1975 specifically for the CIT/SIO project;
   d) 10 stations have 1 to 2 years of bedload data;
   e) 11 of the 20 stations above are on the mainstem of rivers near their points of discharge to the ocean.

   One hundred and ten station-years of daily suspended-sediment discharge data are available from the USGS. These data have been obtained in punched-card format and have been entered onto magnetic tape and disk. Data on the particle-size distribution of suspended sediment and bedload are being entered onto computer cards for immediate analysis and subsequent entry onto tape or disk.

3. Geologic data: A extensive set of regional and subregional geologic maps.

4. Aerial imagery: an inventory of existing imagery shows that more than 100,000 images are available for the study area from the USGS, National Aeronautics and Space Administration, U. S. Forest Service, and other public and private sources. A compilation of flight lines, image centers, and image scales for USGS, NASA, NOAA, and USFS data is now on file at Caltech. Additional aerial photography is available at Scripps. A precision scanning stereoscope has been loaned to the project by the USGS for inspection and analysis of stereoimagery.

5. Beach and offshore sediment-size data: size-distribution data for 95 samples in Ventura, Los Angeles, Orange, Santa Barbara, and San Diego Counties by the Los Angeles District, Corps of Engineers, for the period 1967-69. More than 350 additional sand samples at various locations along the coast of the study area were obtained and analyzed by the Corps from 1963 to 1966.

6. Fire history data: acreage burned, locations and dates of forest and brush fires that have occurred in the study area during the past 65+ years. These data have been collected from county agencies and the U. S. Forest Service.

7. Sand and gravel mining data: location, quantity, and size distribution of sand and gravel mined in the study area. (These data will be used to help assess the magnitude of usage and movement of sediment by human activity. A detailed knowledge of the demand for sand and gravel will aid in weighing alternatives for disposal of material that must be excavated from flood-control and debris basins.)

Data compilation work has also included the preparation of special maps. For example:

1. Regional fire histories
2. Geomorphic land types characterized in terms of sediment erosion potentials
3. Drainage basin control areas.

Recently the USGS agreed to publish maps prepared as part of the CIT/SIO sediment management study in a special USGS Hydrologic Atlas series. The first maps to be published in this series will be regional fire history maps. These maps include detailed fire histories for each of the seven counties in the study area back to 1910. Decade maps, i.e. one for each ten-year period 1940-49; 1950-59, etc.; as well as a 66-year composite map showing fire histories are being prepared. Along with the fire maps there will be a brief description in the Hydrologic Atlas of the characteristics of the fire histories (spatial distribution, frequency, etc.) and their physical effects.

II. Preliminary Estimates of Regional Sediment Budget

Using data compiled thus far, some preliminary estimates have been obtained for regional sediment budget factors characterized schematically in Figure 2.

Debris accumulation and sediment discharge data from Ventura, Los Angeles, Riverside, Orange, and San Diego Counties were used to obtain estimates of the mean annual denudation (surface erosion) rates. The results indicate that to a first approximation, there are three characteristically different types of land forms in the study area. The first is mountainous areas, characterized by steep slopes, well-defined features and abrupt vertical reliefs of thousands of meters. This land form is primarily the result of two extremely active morphologic processes: tectonic faulting, and hydraulic erosion. For this land type longer-term mean annual erosion rates of from 0.6-2.5 mm/yr have been measured.

The second land type is hill areas. These areas are geologically mature and have well-rounded features with moderate vertical reliefs of several hundred meters. Limited available data suggest denudation rates in hill areas of approximately 0.2-0.4 mm/yr.

The third type, flatter coastal and upland plains areas, is noted for its smooth features, very gradual slopes, and low relief (tens of meters). Although this land type does yield sediment, the amount is small ($\sim$ 0.01 mm/yr). Plain areas serve primarily as intermediate depositional zones between mountain and hill areas, and the shoreline. (In some areas, of course, the mountain and hill areas drain directly to the shoreline.) Hence, there is generally a net long-term aggradation on plain areas.

Based on these values of mean annual denudation rates, in conjunction with a generalized land form classification of the study area, preliminary estimates were made of mean annual sediment erosion from mountain, hill and plain areas, as follows:

Land Form Areas

Mountains	8,800 km^2
Hills	8,600
Plains	12,600
	30,000 km^2

Land Form Erosion (Mean Annual)

	Unit Rate	Aggregate (all sizes)
Mountains	1. mm/yr	8.8 Million m^3/yr
Hills	0.3	2.6
Plains	0.01	0.1
		11.5 Million m^3/yr

Using the sediment size classification and estimates of particle size distribution shown in Figure 3, the following estimates have been computed for sand (0.064 - 2.0 mm) production.

Sand Production (Mean Annual)

Mountains	3.1 Million m^3/yr
Hills	1.0
Plains	0.02
	4.1 Million m^3/yr

In the study area, sediment deliveries to the shoreline originate from nine major rivers, and more than 80 streams that drain from coastal plains and directly from mountain and hill areas. Based on sediment discharge/accumulation, and streamflow data already compiled at Caltech, estimates have been made of annual sand deliveries to the shoreline, as follows:

Sand Discharge to Shoreline Areas

	Estimated Annual Average*	% of Total	1969 Flood
Major Rivers	m^3		
Ventura	100,000	10%	
Santa Clara	500,000	51	
Los Angeles	10,000	1	10,100,000
San Gabriel	10,000	1	
Santa Ana	75,000	8	2,200,000
San Luis Rey	10,000	1	
Santa Margarita	25,000	3	
San Diego	10,000	1	
Tijuana	5,000	-	
Smaller Streams			
San Juan Creek	40,000	4	1,150,000
Other Streams	200,000	20	
total	985,000	100%	

*Based on 1951-74 period of record. For these estimates it was assumed that sand transport is equal to 30% of total sediment transport.

These estimates suggest that at present approximately 1/4 of the sand produced by land surface erosion is eventually delivered to the shoreline area.

The above table also gives single-year (1969) estimates on three streams. These data indicate that there can be a large variation in annual values of shoreline sand delivery. Data in the following table, collected by the USGS on the Santa Clara River which is relatively uncontrolled further illustrates this annual variation.

Variation in Suspended Sediment Transport (all sizes)
by Santa Clara River Near Mouth

Water Year	Annual Transport Millions m^3	Equivalent Erosion Rate mm/yr
1968	0.043	0.01
1969	29.0	6.9
1970	0.38	0.090
1971	1.4	0.33
1972	0.27	0.064
1973	2.4	0.59

These variations (nearly three orders of magnitude) in annual sand supply to the shoreline suggest that under natural conditions there can be significant year-to-year fluctuations in shoreline configuration and beaches near major river mouths. The amplitude and down-shore extent of these natural fluctuations have not yet been determined.

Preliminary data indicate that during the past 30 years, more than 400 million cubic meters of sedimentary material have been mined by sand and gravel producers, some 40 million m^3 of sediment has been removed and relocated from reservoirs and debris basins, and more than 110 million m^3 of sand-sized sediment has been artificially placed on beaches in southern California for widening and nourishment through coastal dreding operations. Additional dredge-spoil sediment has been used for land fill or disposed of in offshore areas.

These data suggest that the scale of man-induced sediment movements is of the same order of magnitude (1-10 million m^3/yr) as natural sediment movements, and perhaps most significantly man's activities (artificial nourishment) along the shoreline have had a first-order effect on beach stability and configuration.

III. Secondary Studies

At present, in addition to ongoing data compilation and the mapping tasks described previously, work is under way to improve the above estimates of erosion from mountain and hill areas by identifying additional predictive parameters and developing a more accurate model which may be used to estimate sediment yields from individual watersheds. This will enable a more accurate and geographically detailed definition of sediment production from upland areas. Efforts are also under way to obtain accurate estimates of yearly sediment deliveries to the shoreline by major rivers from 1925 to 1975 based on (a) actual conditions that have existed, and (b) natural conditions (streamflows) that would have obtained without the advent of artificial controls. This analysis will provide accurate estimates of the effects upstream control structures have had on sediment deliveries to the shoreline area during the past 50 years.

In the detailed studies now under way inland areas have been classified as being either geologically erosional or depositional. Generally mountains and hills are erosional surfaces while river valleys and coastal flood plains are depositional. Figure 4 is a photo reduced copy of a 1:250,000-scale working map that has been constructed to define erosional and depositional surfaces in the study area. The boundary between inland erosional and depositional landforms provides a natural boundary through which to define sediment flux. A second such natural boundary is the shoreline. In some cases these boundaries essentially coincide, e.g. San Juan Creek. We have chosen in the studies currently under way to consider primarily sediment flux (amount and size distribution) across these two boundaries.

In each case, with the erosional/depositional boundary and the inland/ocean boundary, sediment flux is not uniform. It is concentrated at discrete locations along the boundary called stream channels. There is, however, some natural lateral migration of these concentration points along the boundary with time. The sediment transport at each concentration point is the result of processes acting on the inland area of higher elevation and contributing surface runoff to this point. This area is called the catchment or watershed above the concentration point. The flux across a boundary during a given time period (storm, year, century) then is the composite of all individual transports at the concentration points. It should be noted that there can be large temporal and spatial variations in transport rate at the concentration points along a given boundary.

In defining the sediment flux at a concentration point on either of the two boundaries two characteristically different approaches are available. The first might be thought of as the "engineering approach" wherein the output function, streamflow and sediment discharge, are measured over a period of years. The time series defined by these data can then be correlated with time series' at other concentration points and the sediment flux across the particular boundary defined as a function of time (frequency) and location.

The second technique (geologic approach) seeks to develop an aggregate model of geomorphic processes on the watershed which can be used to predict output: streamflow and sediment discharge. The model is based on watershed characteristics and climatic input.

Each of the two approaches has comparative advantages and disadvantages. Because of the extremely complex processes operative in a natural watershed it is very difficult to develop an accurate predictive model based on watershed characteristics as with the geologic approach. However, often input data for such a model are more readily obtained than the sediment discharge and streamflow data required in the engineering approach. Also output data alone (engineering approach) do not enable a detailed understanding of watershed processes or the effect of changes in watershed conditions or climatic input. Output data, though, when available, do in general enable more accurate estimates of watershed behavior (annual runoff, peak discharge, sediment yield, etc.) than geologic-type models.

In the CIT/SIO study area there are watersheds draining through the boundaries defined above which range from less than 0.1 km^2 to more than 10^3 km^2, and watersheds wherein streamflow and sediment discharge have been measured and many where there have been virutally no output measurements. A large number of these latter watersheds lie along and drain directly to the shoreline.

Therefore in order to treat all of the important watersheds which contribute sediment to the boundaries defined above, each of the two approaches must be employed. The advantages of being somewhat forced to employ both approaches are that our overall understanding of watershed sediment transport processes will be enhanced and a greater accuracy should be realized through a comparison of results from two independent techniques.

We have two primary studies currently under way in which the strategies being employed are representative of the two different approaches described above.

A. Major Rivers Study

On each of the nine major rivers draining to the shoreline in the study area, streamflow and limited sediment discharge data are available. These rivers include the Ventura, Santa Clara, Los Angeles, San Gabriel, Santa Ana, Santa Margarita, San Luis Rey, San Diego, and the Tijuana which has a large part of its drainage in Mexico. The objective is this substudy is to quantify the beach sized sediment delivery to the shoreline each year from 1925-75 on these rivers and accurately estimate the natural sediment deliveries by the rivers that would have taken place under pristine conditions without the advent of flood control and water conversation facilities during this period. 1925-75 was chosen because is has been during this period that most of the significant human development in southern California has taken place, and also the period during which almost all of the available historical streamflow/sediment discharge data was collected. Periods of measurement on the nine different rivers vary from a few years to more than 50 years.

The Ventura River was the first of the nine rivers chosen for analysis in this sub-study. Results thus far on this river are definitive and have been outlined in a recent Newsletter article written by William R. Brownlie and David J. Sarokin. A copy of this article is included with this report as Appendix C.

As indicated in the article similar studies on the other eight rivers are currently under way. With two or three of these rivers available data and the size of the watershed enable an analysis procedure much like the one employed on the Ventura River. However, with the remaining rivers, due primarily to a lack of historical data and/or the early advent of significant human controls on the river, the hydrologic analysis is more complex. Such is the case with the Santa Ana River.

The Santa Ana is the largest (drainage area) and longest river in the study area. It contains in one form or another all of the complications found in any of the other rivers as well as some unique natural and man-made characteristics that further complicate analysis. Early human developments on the Santa Ana during the latter part of the 19th century diverted river water for agricultural and municipal use and electric power generation. The agricultural and municipal use (including groundwater recharge) on the Santa Ana have continued to increase in this century. While there are no major water conservation structures, smaller storage reservoirs have been built on San Antonio Creek, Big Bear Lake, the San Jacinto River, and Santiago Creek.

The San Jacinto River which might be thought of as a tributary to the Santa Ana drains a large anomolous closed basin. Lake Elsinore is a natural lake bed which serves to contain surface runoff in the basin. There is a 40' natural divide between this basin and the main part of the Santa Ana River Basin. Because of this natural barrier the San Jacinto drainage is a closed basin with no surface runoff to the coast except in very wet years. Lynch* has attempted to reconstruct the historical changes in surface elevation in Lake Elsinore (see Figure 4) to identify the frequency with which this natural overtopping takes place.

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*"Rainfall and Stream Runoff in Southern California Since 1769", by H. B. Lynch, the Metropolitan Water District of Southern California, August 1931.

During the past +30 years surface flows in the lower reach of the Santa Ana River have been modified by the construction of Prado Dam, and extensive channelization.

There are 68 USGS gaging stations at various locations on the lower and upper Santa Ana (11 additional stations in San Jacinto Basin) with lengths of record varying from 2 to 72 years. There are also five active USGS sediment discharge measurement stations along the river.

The analysis procedure being used on the Santa Ana involves the construction of annual river surface water budgets (1925-75). The annual budgets are obtained by quantitatively identifying individual inputs, uses and losses to surface runoff all along the river to the shoreline. Using these data and available gaging records actual historic flows can be synthesized as well as probable natural flows that would have obtained without human controls. With these flows, available sediment discharge data on the Santa Ana, and data from other rivers which preliminary analyses suggest behave similarly, the desired dual (actual versus natural) 50-year time series of beach-sized sediment deliveries to the shoreline can be defined. It is felt that without an analysis such as this questions pertaining to the quantitative effects of past or possible future human developments on sediment transport by the Santa Ana River or the natural behavior of the river will remain unanswered. A detailed outline of the hydrology of the Santa Ana River is also necessary for understanding this natural system's effects on the closely linked coastal beaches, and adequately evaluating contemplated future changes in river use and control.

We hope to complete the Major Rivers Study by the end of 1977.

B. Upland Watershed Study

Many of the watersheds transporting sediment from the erosional upland areas to depositional fans and coastal plains, or to the shoreline area, have not been gaged for streamflow or sediment discharge. In order to predict annual and longer-term sediment delivery by these watershed areas it is necessary to 1) identify the parameters that are causally important in the processes of erosion and transport, and 2) develop a model that quantitatively relates these parameters to watershed sediment production.

The data in our study area that are available for the development and testing of such a model includes:

1. Short and longer-term sediment accumulation data for more than 100 reservoirs and debris basins distributed non-uniformly throughout the study area.
2. Surficial geology (parent material, slope stability) maps of selected areas within the region.
3. USGS Topographic Maps
4. Precipitation data for several hundred rainfall stations distributed, non-uniformly throughout the study area with records varying from a few years to more than 100 years.
5. Tectonic and seismic maps which define local faulting and levels of earthquake activity. (These maps help to identify the effects of tectonic activity on watershed morphology and the structural condition of the parent material; also the relative effect of seismic activity in effecting mass movements on a watershed.)

One can conceptually identify four general factors which are primarily responsible for watershed sediment yield. They are:

1. Topography
2. Vegetation (including fire history)
3. Surficial Geology
4. Precipitation

In comparing these four factors with the data set described above (plus streamflow/sediment discharge data on other watersheds) it is apparent that while there is a large body of data, the available data set in each of the four general categories is less than optimal. This problem is smaller with topographic and precipitation data than with surficial geologic data, and the lack of any quantitative data on vegetative cover (except fire history data).

The first step in the current analysis has been to study a cluster of watersheds wherein there is a large body of field data, but some homogenity such that in the four general factors affecting sediment yield there is a reduced number of parameters which vary significantly among the watersheds. The limited heterogeniety facilitates an initial quantitative identification of some parameters affecting watershed sediment delivery, and will enable formulation of a basic model.

The second step will be to include the larger data set available (entire study area) to modify and extend the basic model for application elsewhere in the study area.

The relatively large body of data available on watersheds in the San Gabriel Mountains and the general similarity of these watersheds led to this area being chosen for the initial step in the detailed watershed analysis. The reduced data set chosen for initial consideration includes watersheds above twelve flood control reservoirs and five debris basins. These structures are essentially total containment facilities in terms of sediment yield. The seventeen watersheds are identified in the following table.

Study Watersheds in the San Gabriel Mountains

Debris Structure	Area (km^2)
West Ravine	.65
Los Flores	1.17
Dunsmuir	2.18
Brand	2.67
Haines	3.96
Sierra Madre	6.19
Live Oak	6.48
Thompson Creek	7.77
Sawpit	8.65
Big Dalton	11.6
Santa Anita	28.0
San Dimas	42.0
Pacoima	73.0
Devils Gate	82.6
Cogswell	101.5
Big Tujunga	213.2
San Gabriel	423.5

In Figure 6 watershed area versus measured average denudation rate (DR) for 1939-69 are plotted for these watersheds. The watershed areas in Figure 6 vary over three orders of magnitude and DR varies from 0.6 to 2.5 mm/yr. The denudation rate is computed as the average rate of net sediment erosion over the horizontal surface of the watershed. The trend line fitted to these data suggests that part of the variation in DR is due to a variation in watershed area. This line indicates a reduction in mean annual denudation rate with watershed area. Such a variation has been noted by other investigators. Probable reasons for such a general reduction in mean DR are that as watershed area increases 1) mean slopes tend to be reduced and thus there is a reduced erosion potential and a greater probability of internal deposition of eroded material, and 2) peak rainfall intensities during storms tends to become non-uniform and thus less erosive.

What causes the variation from a smooth relation between DR and watershed area among these watersheds? The answer to this question lies in individual differences among the watersheds which we are currently seeking to identify and then quantitatively relate to the measured variances in DR.

IV. Scripps Studies

At Scripps efforts are under way to inventory and compile the large body of beach profile data collected by the Corps of Engineers, and State and County agencies over the past 30-50 years. These data will be used to define seasonal fluctuations and long-term changes that may be taking place on the beaches. The results from this effort will help to define the range of seasonal changes in beach configuration and the shoreline throughout the study area and identify those areas undergoing a depletion of beach sand.

There is a second effort under way at Scripps to compile available longshore transport data for each of the five major littoral cells defined in the southern California region (Figure 7). Each littoral cell will then be examined in terms of its sediment budget: the input from land versus the losses to offshore basins and downcoast cells. This type of analysis will show which cells have insufficient sediment input to balance their longshore transport potential and offshore losses.

Appendix A contains tentative outlines of all sub-tasks that are intended for the Caltech and Scripps efforts, respectively, during the Planning and Assessment Phase of the Sediment Management Project.

APPENDICES

APPENDIX A

Brent D. Taylor
21 January 1977

PRELIMINARY

OUTLINE OF CIT/SIO SEDIMENT MANAGEMENT PROJECT
TASKS TO BE COMPLETED DURING THE PLANNING & ASSESSMENT PHASE

The primary study objectives for the initial phase of the CIT/SIO project are:

1. With available data, develop best possible estimates of annual regional sediment movements, and identify the specific effects man-made controls have had on the natural regional sediment budget.

2. Prepare preliminary definition of technical alternatives in regional sediment management that might be used to alleviate existing sediment balance problems, e.g. inland debris disposal, beach stability.

3. Define research efforts needed to provide an adequate understanding of regional sedimentation processes. (These research efforts will be undertaken in later phases of the project).

4. Identify additional field data needs to adequately define regional sedimentation processes and overall sediment budget. (Additional field measurements will begin as soon as feasible after recognition of specific needs, e.g. USFS began ongoing sediment discharge measurements at the mouths of the Los Angeles and San Gabriel rivers during the winter of 1975-76 as part of this project.)

5. Design optimal strategies for ongoing field data collection in support of regional sediment management analyses.

In order to achieve these objectives a specific work program has been developed and is under way. This program outlined in detail in the following section is based on:

1. A complete inventory of available existing field data;

2. Centralized compilation of useful existing data in optimal format, e.g. computerized digital files, maps, etc.

3. Analyses utilizing field data compilation

In addition to achieving the five primary objectives project output during the initial phase will include:

1. Maps

2. Data Files

3. Analyses techniques, e.g. model for estimating annual watershed sediment production.

The planning and assessment phase is scheduled for completion in June 1978, when a formal report will be published to describe in detail all study results obtained thus far.

Following are detailed outlines of the sub-tasks to be undertaken at EQL and SPL during the initial project phase, work flow and project outputs.

EQL Technical Work Outline

A. Prepare preliminary (first order) estimates of mean annual sediment erosion and shoreline sand deliveries to compre with available estimates of littoral sand transport and losses along the shoreline, and estimates of the scale of artificial sediment movements, e.g. dredging, to ascertain general scales of primary factors in current regional sediment budget.

   1. Using general relation between streamflow and sediment discharge defined by existing data, estimate average annual sand deliveries to shoreline area by coastal streams.

   2. Using generalized erosion rates for different land types based on available debris production data, estimate total average annual erosion from mountain areas, hills, and coastal plains.

B. Prepare geographically-detailed, best possible estimates of annual and mean annual inland sediment erosion and deposition, and shoreline sediment deliveries during the past 50 years (period of important human development) under actual conditions, and natural conditions that might have obtained without human development.

   1. Define sediment transport characteristics of coastal streams flowing over alluvial plains using available streamflow and sediment discharge data, and existing analytical techniques, e.g. Modified Einstein Method.

      a. Define streamflow/sediment transport relations for coastal streams and rivers

      b. Construct 50-year (1925-75) time-series of streamflow parameters, e.g. peak discharge, annual runoff, which may be used to estimate annual sediment transport, for 1) historical (actual) conditions, and 2) hypothetical uncontrolled (natural) conditions.

(Prepare 1:250,000 scale map of mean annual runoff. [General distribution]).

c. Define historical changes in stream drainage networks including location of stream mouths along the shoreline

   (Prepare 1:250,000 scale map of historical changes in stream drainage networks. [Working map only, limited distribution.])

d. Define natural morphology of presently-controlled lower reaches of streams, especially with regard to flood plain spreading and selective load deposition.

2. Define sediment production characteristics of upland watersheds, wherein sediment transport characteristics of streams are more complex than with 'flood plain' alluvial streams, by developing a multiple-regression model which may be used to estimate annual watershed sediment production.

   (Prepare 1:250,000 scale map of watershed areas and larger drainage basins, (General Districution)).

   a. Identify watershed precipitation parameters which correlate best with sediment production.

      (Prepare 1:250,000 scale maps delineating regional variations in precipitation parameters which best characterize meteorological sediment erosion potentials. (General Distribution)).

   b. Identify topographic parameters which best characterize, according to statistical correlation, topographically-related sediment erosion potentials.

      (Prepare 1:250,000 scale maps delineating relative topographic sediment erosion potential. (General Distribution)).

   c. Identify geologic parameters which best characterize related sediment erosion potentials, e.g. recent depositional/erosional areas, lithology of erosional areas.

      (Prepare 1:250,000 scale maps delineating important surficial geologic parameters. (General Distribution)).

   d. Define the net quantitative effects of fire on annual sediment production on upland watersheds/

      (Prepare 1:250,000 scale maps of regional fire histories by decade and composite for past 75+ years).

   e. Investigate the quantitative effects of 'check dams' on watershed sediment production.

      (Prepare a 1:250,000 scale map identifying artificial sediment-movement controls, with type on a degree of control delineation. (General Distribution)).

3. Define effects of natural nearshore controls (lagoons and berns) on stream sediment deliveries to the ocean.

C. Prepare a detailed geographic definition of artificial sediment movements during the past 75+ years.

(Prepare a 1:250,000 scale map identifying locations, dates, volumes, and size distribution of sediment removed and deposited by man. (General Distribution)).

1. Compile data on all reservoir, debris basin, check dam, and channel cleanouts (locations, dates, amounts, sediment sizes, and disposal usage sites).
2. Compile data on historical sand and gravel mining (locations, dates, amounts, material sizes, general usage areas).
3. Compile data on coastal dredging, sand bypass, and artificial beach nourishment (locations, dates, amounts and sediment sizes).

D. Define specific additional research efforts necessary to provide for an adequate understanding of all important regional sedimentation processes, and definition of regional sediment budget factors. (These research needs will be identified primarily through work incident to tasks and sub-tasks previously defined.)

E. Define specific additional data needed to enable a comprehensive and accurate definition of regional sedimentation processes and sediment budget factors. (These data needs will be identified through work incident to tasks and sub-tasks previously defined.)

F. Develop rational strategies for ongoing field data collection and processing which may be used by various government agencies involved in regional sediment management and field data collection. This development will be based primarily on results (data usage and needs and analysis procedures), obtained in tasks B.C and D.

G. Develop preliminary definitions of technical/policy alternatives which may be used to alleviate regional sediment balance problems.

F. Prepare final report on Planning & Assessment Phase.

<u>EQL Project Output</u>

Maps:

1. 1:250,000 scale map identifying mean annual runoff by watershed and larger drainage basins in CIT/SIO study area. (Available: June 1977).
2. 1:250,000 scale maps of regional fire histories by decade and composite for past 75+ years. (Available: July 1977).
3. 1:250,000 scale maps of topographic and geologic parameters closely related to sediment erosion potential. (Available: August 1977).
4. 1:250,000 scale map identifying man-made sediment-movement controls by watershed and larger drainage basin, with delineation of type and

degree of control. (Available: August 1977).

5. 1:250,000 scale map identifying historic man-induced sediment movements (dredging, reservoir cleanouts, sand & gravel mining, artificial beach nourishments). (Available September 1977).
6. 1:250,000 scale contour maps of meteorological (precipitation) parameters closely related to sediment erosion potential. (Available December 1977).
7. 1:250,000 scale map delineating individual watershed areas and longer drainage basins. (Available: January 1978).

Data File Output:

All data output will be included with map and/or publication output as appropriate. Data output will consist of an identification of specific data files available, their original source, form of the data, e.g. tabular, computer cards, tapes, etc., a general description of data quality, and recommended procedure for obtaining a copy of the data set.

Publications:

- Newsletters: Fall 1976, Spring 1977, Fall 1977, Spring 1978
- Papers to be published in open literature, or in EQL Technical Memorandum series (tentative):
  - "Effects of inland control structures on annual coastal sediment deliveries in Southern California"
  - "Sediment transport relations for alluvial streams in Southern California:
  - "A quantitative description of regional inland sedimentation processes in Southern California"
  - A statistical model for estimating sediment production from watersheds in Southern California"
  - "Topographic and geologic factors in watershed sediment production", ASCE Conference, Sept. 1977.
  - "Effects of fire on sediment production in Southern California"
  - "The effects of natural nearshore controls on sediment deliveries to the ocean by coastal streams"
  - "A rational strategy for the collection of field data to define inland sediment movements"
  - "The coastal sediment balance in Southern California" (with Scripps).

Special:

1. Workshop on "Sediment Management for Southern California Mountains, Coastal Plains, and Shoreline," March 15-16, 1976.

APPENDIX B

SEDIMENT MANAGEMENT CONFERENCE, 15-16 MARCH 1976

List of Attendees *

Allen, Gerald - Fugro, Inc., Long Beach
Anderson, Henry W. - U.S. Forest Service, Berkeley
Andrews, Ned - Dept. of Geology, UC Berkeley
Angelos, Richard E. - Calif. Dept. of Water Resources, L.A.
Appel, David H. - USGS, Laguna Niguel
Armstrong, George A. - State of California, Dept. of NOD, Sacramento
Aubrey, David - Scripps Institution of Oceanography, La Jolla
Aulick, Mike - Comprehensive Planning Organization, San Diego
Aygarn, Ron - Angeles National Forest, Pasadena

Baumli, George R. - Dept. of Water Resources, L.A.
Bellmer, Russ - Corps of Engineers, L.A.
Berry, Joe - San Diego Flood Control Dist.
Bertucci, William F. - Marine Bio. Cons., 947 Newhall, Costa Mesa
Bickel, Gerald - Ventura County Public Works
Boehm, John C. - Reg. Water Quality Cont. Bd., L.A.
Brady, Matthew - Calif. State Lands Comm., Sacramento
Brancheau, Ed - San Diego Gas & Elec.
Brisco, John - Office of Attorney General, San Francisco
Brooks, Norman - EQL, Caltech
Browand, F. K. - USC
Browerman, Frank - CDM, Inc. Environmental Engineers, Pasadena
Brown, William - EQL, Caltech
Bruington, Arthur - L.A. County Flood Control Dist.
Bruno, Richard O. - Army CERC, Pt. Mugu
Bugescu, Ibolya - Cal State Long Beach
Bulot, Mark - Fourth Street Rock Crusher, San Bernardion
Burtman, L. - San Diego Water Quality Cont. Bd.

Cain, Robert E. - City of San Diego
Caldwell, Joe - consulting engineer, Arlington, Virginia
Campo, Paul - Nat. Res. Off., Marine Corps Base, Camp Pendleton
Cass, Glen - Caltech
Chang, Howard H. - San Diego State U
Chen, Kenneth - Env. Eng. Prog., USC
Chu, H. L. - Cal State Long Beach
Cleveland, George - State Div. Mines & Geol., Cal Poly, San Luis Obispo
Clifton, H. Edward - USGS, Menlo Park
Collins, Win S. - Corps of Engineers, L.A.
Conrad, C. Eugene - San Dimas Experimental Forest, Glendora
Copeland, Ronald - Corps of Engineers, L.A.
Costa, Steve - Foundation of Ocean Research, San Diego
Couchman, Walter - City Engineers Office, L.A.
Crandall, Thomas A. - State of Calif., San Diego Coast Reg. Comm.
Culbertson, Don - USGS, Menlo Park
Cushman, Marjorie - Corps of Engineers, L.A.

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*Incomplete

Davis, J. Dan - L.A. County Flood Control Dist.
Dean, E. Nelson - San Bernardino National Forest
Delaney, Ladin H. - Calif. Reg. Wtr. Qual. Cont. Bd., San Diego Region
De La Parra, Ralph - Southern Calif. Edison, Rosemead
Dingler, John R. - USGS, Menlo Park
Dudley, George A. - Calif. Div. of Forestry, Riverside
Durkan, Ray - Caltech

Eagleson, Peter - Caltech
Eilers, Peter H. - Dept. of Geog., Cal State Fullerton
El-Fadly, Abdel Hamid - Cal State Long Beach
Emigh, Glenn - Corps of Engineers, L.A.
Engstrom, Wayne N. - Dept. of Geog., Cal State Fullerton
Eshelby, Courtice F. - L.A. County Flood Control Dist.
Eshett, Ali - Cal State Long Beach

Fisher, Charles N. - Corps of Engineers, L.A.
Frank, Franklin - Calif. Div. of Forestry, Sacramento
Frank, William - Ventura County Public Works Agency
Frautschy, J. D. - Scripps Institution of Oceanography, La Jolla

Garrett, Allen W. - Corps of Engineers, L.A.
Ginn, George W. - Calif. State Lands Div., Long Beach
Gonzales, Dionicio - Corps of Engineers, L.A.
Goring, Derek - Caltech
Gorsline, D. S. - Dept. of Geol. Sci., USC
Gray, Donald - Oak Ridge Nat. Lab., Oak Ridge, Tennessee
Greenhood, Joan - San Diego Flood Control Dist.
Grove, Robert - Southern Calif. Edison, Rosemead

Habel, John - Dept. of NOD, Sacramento
Hale, John S. - Dept. of County Eng., L.A.
Hall, Omeir D. - L.A. County Flood Control Dist.
Hashimoto, Lewis - Caltech
Hatfield, Don - S&F/C County of San Diego
Hayter, William - State Lands Comm., Sacramento
Heacox, Lynn J. - Coastal Zone Comm., Long Beach
Helm, Haden - Corps of Engineers, L.A.
Herrera, Stephen - Calif. Reg. Wtr. Qual. Cont. Bd., Santa Ana Region
Herron, William J. - Moffatt & Nichol Eng., Long Beach
Hill, Joseph C. - Dept. of San. & Flood Cont., San Diego
Hirsch, Robert - Johns Hopkins U, Baltimore, Maryland
Holland, Mel - State Water Resources Cont. Bd., Sacramento

Inman, Douglas L. - Scripps Institution of Oceanography, La Jolla
Iungerich, Russell - Attorney General's Office, L.A.

Jen, Yuan - Tetra Tech, Pasadena
Jeng, Raymond I. - Cal State Los Angeles
Johnson, Gary - City of Seal Beach

Kalkanis, George - USDA, SCS, Davis
Kelley, Frederic R. - Calif. Div. of Mines & Geol., San Francisco
Kennedy, Michael - Calif. Div. of Mines & Geol., Scripps Institution of Oceanography
Knight, Harold B. - State Dept. of Water Resources, Sacramento
Koh, Robert - Caltech
Koplin, Robert - Corps of Engineers, L.A.
Krieger, Jerold - Dept. of Justice, L.A.

Lee, Jiin-Jen - USC
Lenocker, W. Tracy - Cal State Long Beach
Lewis, Tracy - Caltech
Leyman, Larry - Fullerton College
Light, Simon - Corps of Engineers, L.A.
Lillevang, Omar J. - consulting engineer, 626 Wilshire Blvd., L.A.
Lindgren, Donald R. - L.A. County Flood Control Dist.
List, E. John - Caltech
Longfield, Robert - USGS, Laguna Niguel
Lutz, Stan - Corps of Engineers, L.A.

Magoon, Orville T. - Coastal Eng. Br., U.S. Army Div., San Francisco
Marsh, James A. - U.S. Forest Service, Region 5, San Francisco
McCullough, C. A. - Calif. Dept. of Water Resources, Sacramento
McMurry, Pamela - Caltech
McMurry, Peter - Caltech
Menard, H. William - Scripps Institution of Oceanography, La Jolla
Moore, George T. - Chevron Research, La Habra
Morton, Paul - Calif. Div. of Mines & Geology
Mostafa, M. Gamal - Cal State Long Beach
Muldavin, Clark - Calif. Dept. of Parks and Recreation, Sacramento
Muslin, Dan - Corps of Engineers, L.A.

Nakasone, Herbert - Env. Mgmt. Agency, Santa Ana
Naumann, Jeffrey - L.A. Harbor Dept., San Pedro
Nelson, Carl - Env. Mgmt. Agency, Santa Ana
Nichol, John M. - Moffatt & Nichol Eng., Long Beach
Nordstrom, Charles E. - Scripps Institution of Oceanography, La Jolla
Norouzi, Hadi - L.A. County Flood Control Dist.
Nowak, Gerald - Ventura County Public Works

Ouchi, T. - Corps of Engineers, L.A.

Pawka, Steven - Scripps Institution of Oceanography, La Jolla
Pederson, Gary L. - USGS, Menlo Park
Perrin, Robert E. - L.A. County Flood Control Dist.
Pitzer, Allan - Dept. of Water & Power, L.A.

Raichlen, Fredric - Caltech
Reitmeier, Hal - County of Orange, EMA, Santa Ana
Reynolds, James H. - Whittier College
Robertson, Alexander - Southern Calif. Edison, Rosemead
Robinson, David - CDM, Inc. Environmental Engineers, Pasadena
Robles, Al - Corps of Engineers, L.A.
Rogers, Carlton - Pacific Rock & Gravel, Arcadia
Ross, John Robert - Corps of Engineers, L.A.
Ryono, Takashi - Dept. of Water Resources, L.A.

Salas, Eufronio - Ventura County Public Works
Schlachter, William - Moffatt & Nichol Eng., Long Beach
Schultz, Gail - Comprehensive Planning Organization, San Diego
Scott, Kevin - USGS, Irvine
Scott, Ralph G. - Calif. Dept. of Water Resources, No. Dist., Red Bluff
Serr, Eugene F. - Calif. Dept. of Water Resources, No. Dist., Red Bluff
Seymour, R. J. - Dept. of NOD, La Jolla
Sharp, Robert - Caltech
Sholes, Raymond D. - Southern Calif. Edison, Rosemead
Shreve, Ronald - Geol. & Geophysics, UCLA
Simmons, Mike - USDA, Soil Cons. Svc., Santa Barbara
Sonu, Choule J. - Tetra Tech, Pasadena
Soto, W. J. - Cal State Long Beach
Spencer, Donald G. - Corps of Engineers, L.A.
Steller, David - ESCA-Tech Corp., Long Beach
Stone, Katherine - Dep. of Justice, L.A.
Stratton, David W. - Owl Rock Products Co., Arcadia
Stubchaer, James M. - Santa Barbara Flood Control & Water Cons. Dist.
Sturgess, Bryant - State Lands Comm., Sacramento
Sung, Windsor - Caltech
Sweger, John David - Corps of Engineers, L.A.

Taylor, Brent - EQL, Caltech
Tettmer, John M. - L.A. County Flood Control Dist.
Tennyson, Lynn - Whittier College
Terich, Thomas - West Washington St. College, Bellingham, Washington
Tooby, Paul - Scripps Institution of Oceanography, La Jolla

Ukita, Russell - Corps of Engineers, L.A.
Uzes, Bud - State Lands Div., Sacramento

Vance, Harold A. - L.A. County Flood Control Dist.
Van Ingen, Katherine - Caltech
Vanoni, Vito - Caltech

Wark, John - USGS, Menlo Park
Weis, Niels E. - consulting engineer, Longard Pacific, Newport Beach
Williams, John W. - Calif. Div. of Mines & Geol., San Francisco
Williams, Rhea - USGS, Laguna Niguel
Wilson, Ken - Fugro, Inc., Long Beach
Wisz, John J. - L.A. County Flood Control Dist.
Woolley, C. - USMC, Camp Pendleton

Yang, Richard - Dept. of Justice, L.A.
Young, David - So. Calif. Coastal Wtr. Res. Proj., El Segundo

Sediment Discharge on the Ventura River

William Brownlie and David Sarokin

Analysis of data from the Ventura River watershed has resulted in preliminary estimates of the effects of upstream controls on delivery of sediment to the shoreline. Results indicate that the completion of Matilija Dam in 1949 and Casitas Reservoir in 1959 has significantly reduced the total volume of streamflow to the Pacific Ocean, with a consequent decrease in sediment transport.

The Ventura River drains 585 km² of inland drainage. Annual precipitation on this watershed ranges from 40 cm in the lower areas near sea level to more than 80 cm in the mountain areas above 1500 meters. The surface geology is principally comprised of colluvial and landslide deposits developed on the sedimentary bedrock. Vegetation is fairly uniform and consists primarily of chaparral except in the highest parts of the watershed where there are extensive rock outcroppings.

The Ventura River drainage basin, northernmost of the nine major rivers in our study area, was selected as our first attempt at sediment yield modeling. Its small size, good data base and the clarity of its control history provide the basis for a relatively straightforward statistical model of the effect of control structures on sediment delivery to the ocean.

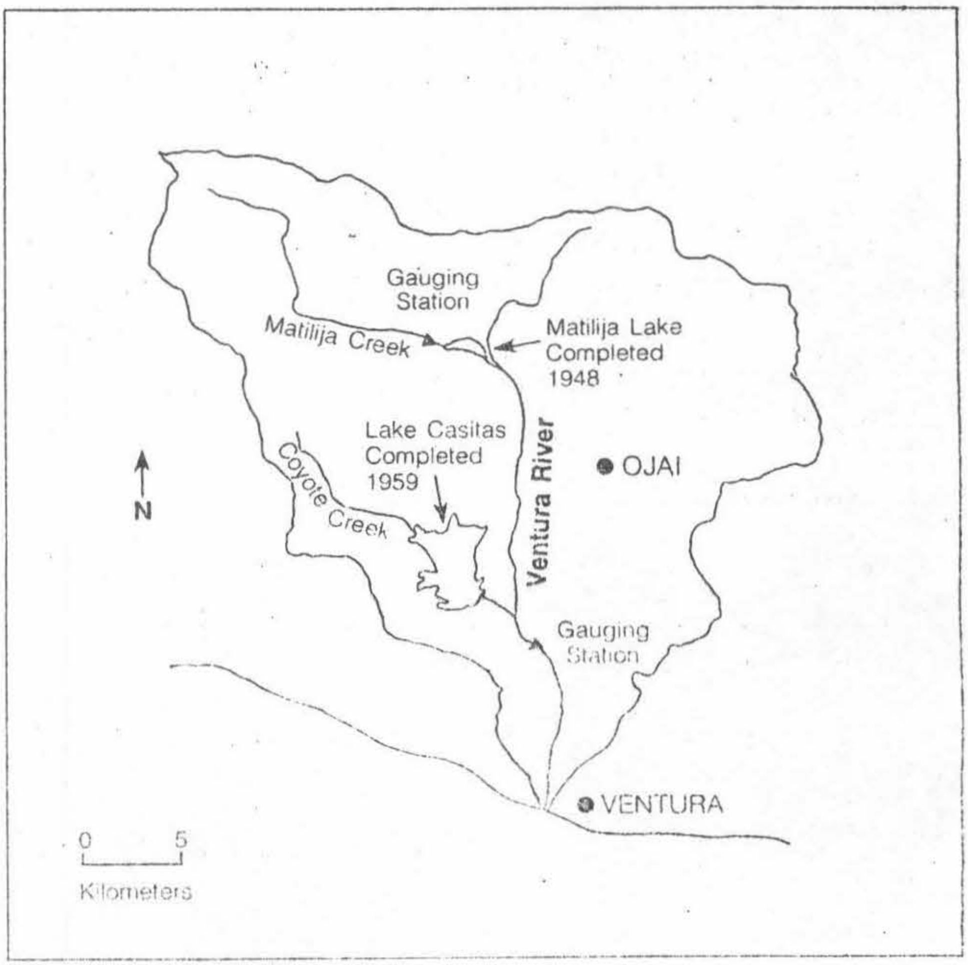
Control structures can influence sediment delivery in several ways. Flood control projects attenuate peak storm flows, but may not necessarily alter the total annual water discharge of a river. Water supply reservoirs, like those on the Ventura River, store the inflow of water, effectively reducing the drainage area of the watershed with a consequent reduction of the annual discharge. Both types of reservoirs trap sediment which would have been delivered to the lower reach of the river.

Our strategy of sediment delivery modeling on the Ventura River has three steps. (1) The first step is the determination of the effect of control structures on the volume of streamflow which is discharged to the ocean. (2) The second step is the establishment of a relationship between streamflow and sediment discharge. (3) Finally, the results from steps (1) and (2) are combined to produce estimates of actual sediment delivery, and sediment delivery as it would have occurred if the control works had not been built. With this general procedure and available data, we were able to obtain quantitative estimates of man's influence on the sediment delivery to the ocean.

The basic technique for step 1 of the modeling is the *Double Mass Analysis.* This technique, as it applies to the Ventura River, is illustrated in the figure on page 10. Here, the cumulative annual discharges for two stream gauging stations have been plotted; thus the term "double mass." Matilija Creek is a small uncontrolled stream, while the Ventura River station is downstream of the two major control structures. The initial section of the curve represents the period 1934 to 1948. During this period human influence on runoff was small. The correlation between the cumulative discharges of the two stations is quite high for this portion of the curve, which is represented as a straight line. The dotted extension of this line provides an estimate of expected cumulative annual discharges from the Ventura River without the influence of the control structures. The effect of the structures, Matilija Dam (1948) and Casitas Dam (1959), is shown to have considerably reduced the discharge from the Ventura River.

Unlike streamflow data, sediment discharge data is relatively scarce for most streams in our study area, and the Ventura River is no

(continued on page 10)

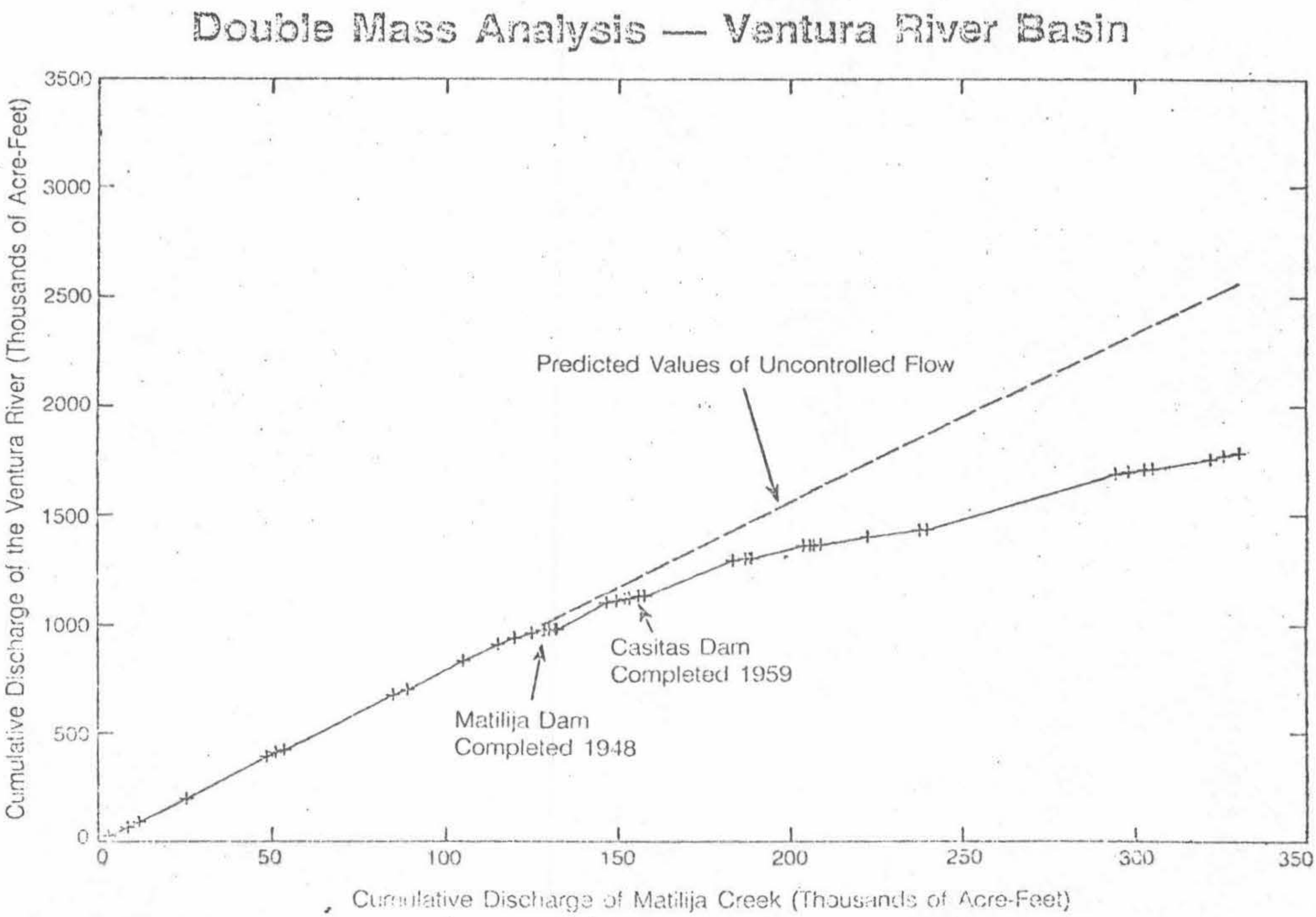


(continued from page 8)
exception. However, the correlation between annual suspended sediment yield and annual runoff is quite high. On a logarithmic scale, the correlation coefficient is 0.99, with the sediment data ranging over three orders of magnitude. The relationship is non-linear in such a way that doubling the annual runoff would approximately triple the annual suspended sediment yield.

Combining the double mass analysis with the sediment rating relationship concludes the sediment modeling procedure. With the completion of Matilija Dam in 1949, the total runoff from the Ventura River, between 1948 and 1958, was reduced by 26% with a corresponding 21% reduction of total sediment yield. In 1959, Casitas Dam was completed and the total runoff for the years 1959 to 1975 was reduced a total of 53%, with a probable sediment yield reduction of 66% for that period. As the study progresses, our analysis will be further refined to produce estimates of absolute quantities of fine and coarse sediment deliveries.

Similar studies are currently underway on the other major rivers in the study area. However, due to the large variation in the data base and artificial river controls, the strategies used on these other rivers may differ from that used on the Ventura River.

Bill Brownlie is a doctoral student in civil engineering at Caltech. Dave Sarokin is a research assistant with the Environmental Quality Laboratory.

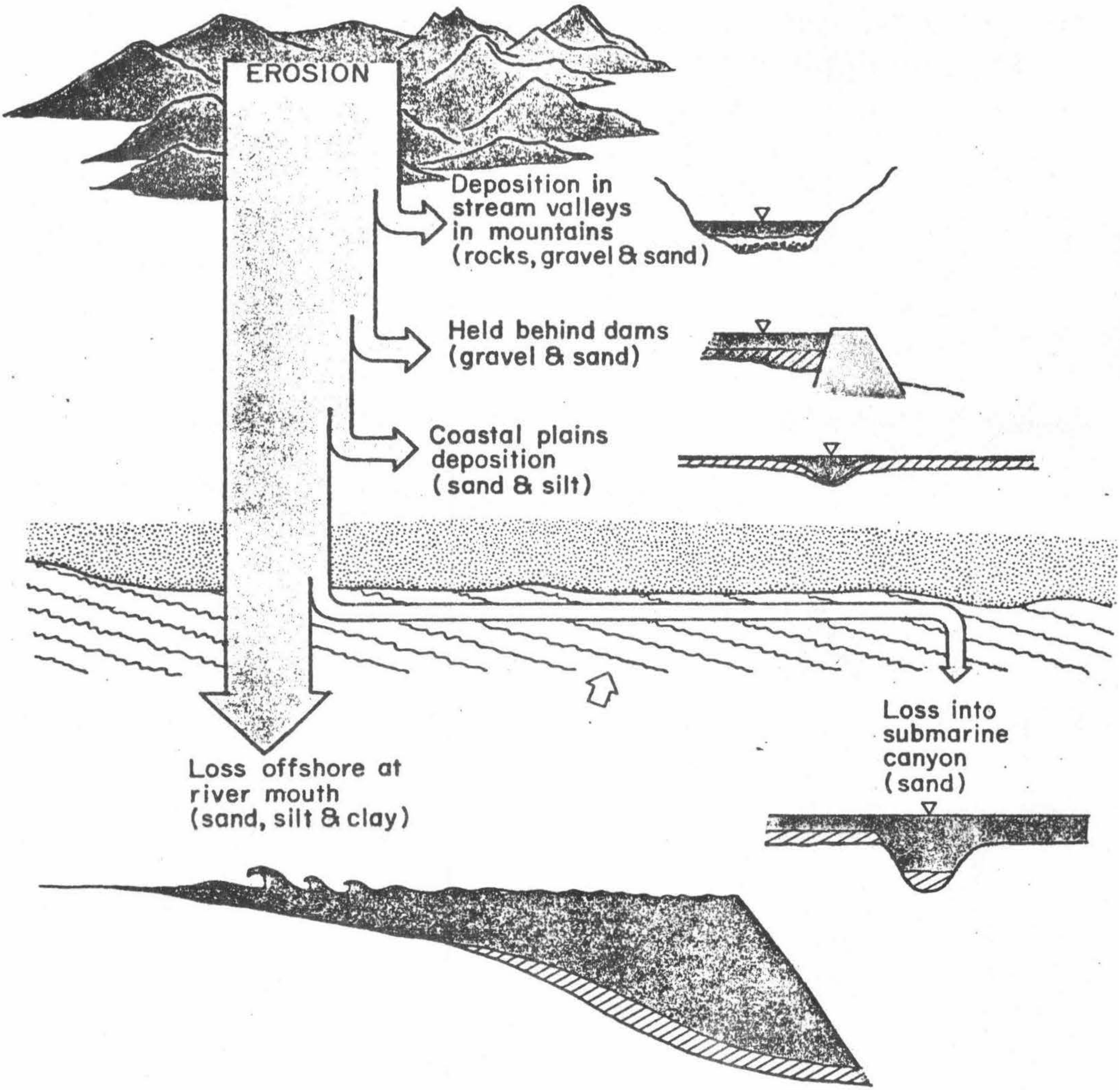


FIGURES

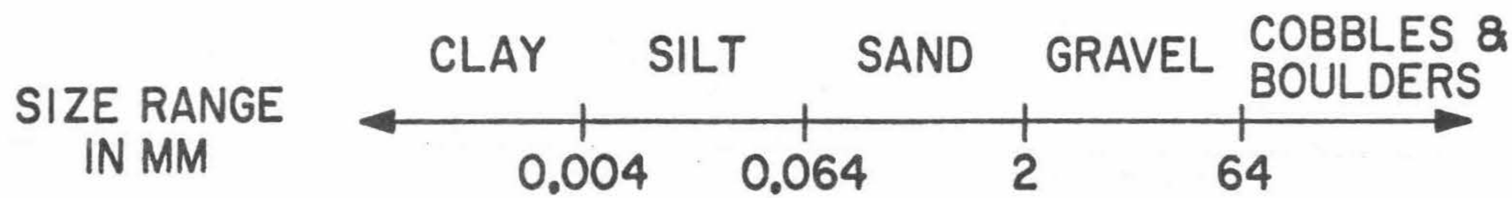

CIT/SIO SEDIMENT MANAGEMENT
STUDY AREA IN
SOUTHERN CALIFORNIA
SANTA BARBARA CO
PT. CONCEPTION
SANTA BARBARA
VENTURA CO
VENTURA
LOS ANGELES CO
LOS ANGELES
SAN BERNARDINO CO
SAN BERNARDINO
RIVERSIDE
RIVERSIDE CO
SANTA ANA
NEWPORT BEACH
ORANGE CO
NEWPORT CANYON
REDONDO CANYON
DUME CANYON
MUGU CANYON
HUENEME CANYON
OCEANSIDE
SAN DIEGO CO
LA JOLLA
SAN DIEGO
DRAINAGE DIVIDE
MEXICO
PACIFIC OCEAN
N
MILES
KILOMETERS
— CIT/SIO STUDY BOUNDARY
--- COUNTY BOUNDARY
11/75

FIGURE 1

FIGURE 2


EROSION
Deposition in stream valleys in mountains (rocks, gravel & sand)
Held behind dams (gravel & sand)
Coastal plains deposition (sand & silt)
Loss into submarine canyon (sand)
Loss offshore at river mouth (sand, silt & clay)

GENERAL SEDIMENT SIZE CLASSIFICATION



PERCENTAGES FOR:

MOUNTAIN EROSION	50%	35%	15%
HILL EROSION	60%	40%	—
PLAINS EROSION	80%	20%	—

FIGURE 3

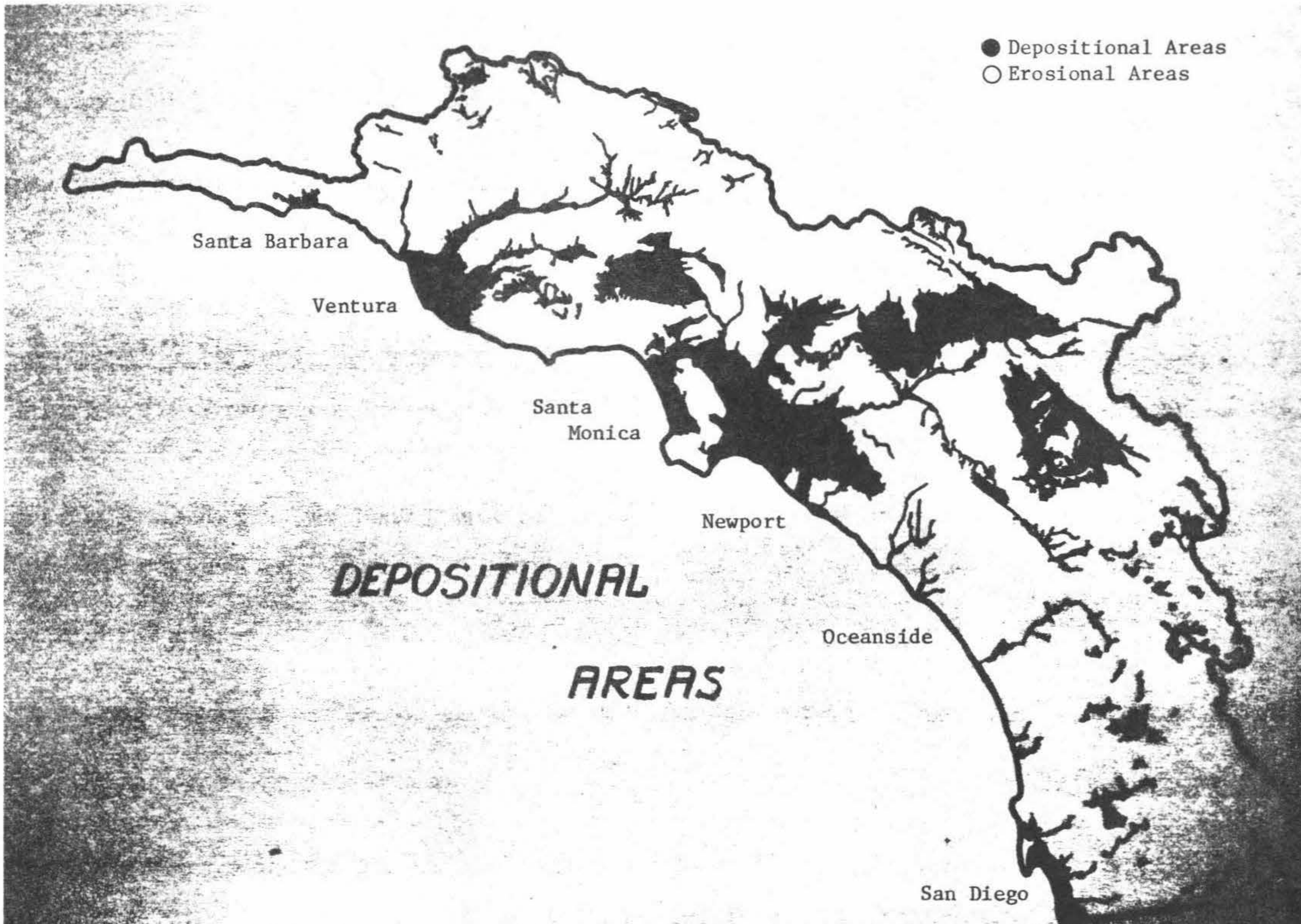


FIGURE 4

Inland depositional areas for natural sediment movements during recent geologic period in Southern California.

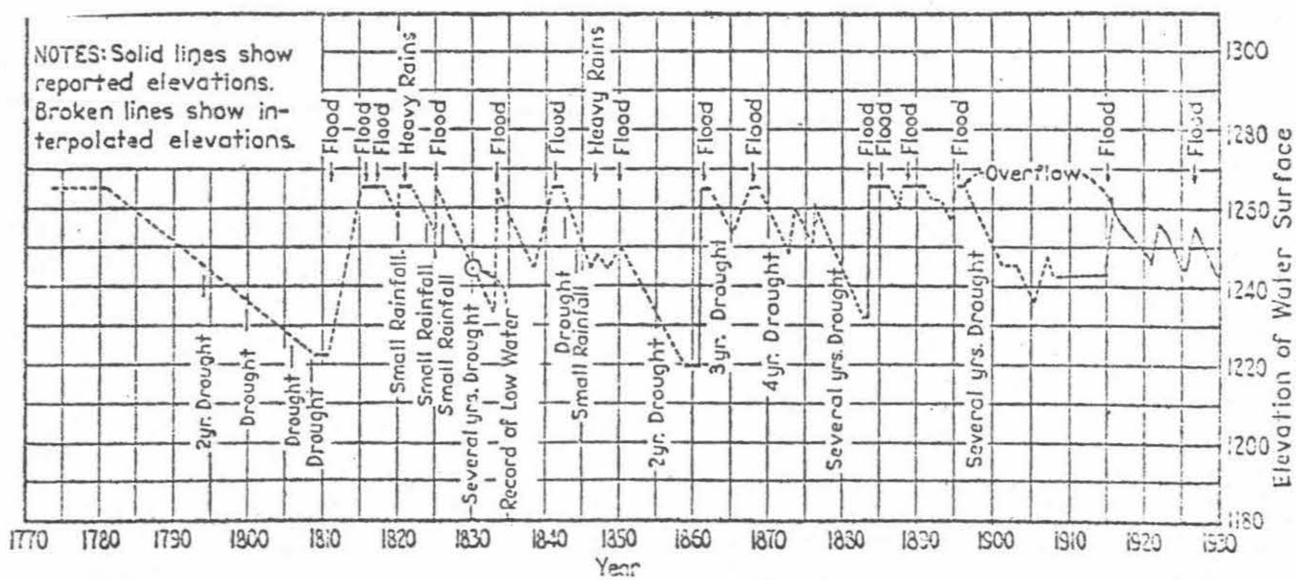


FIGURE 5

Historical water surface elevations in Lake Elsinore
(after Lynch (1931))

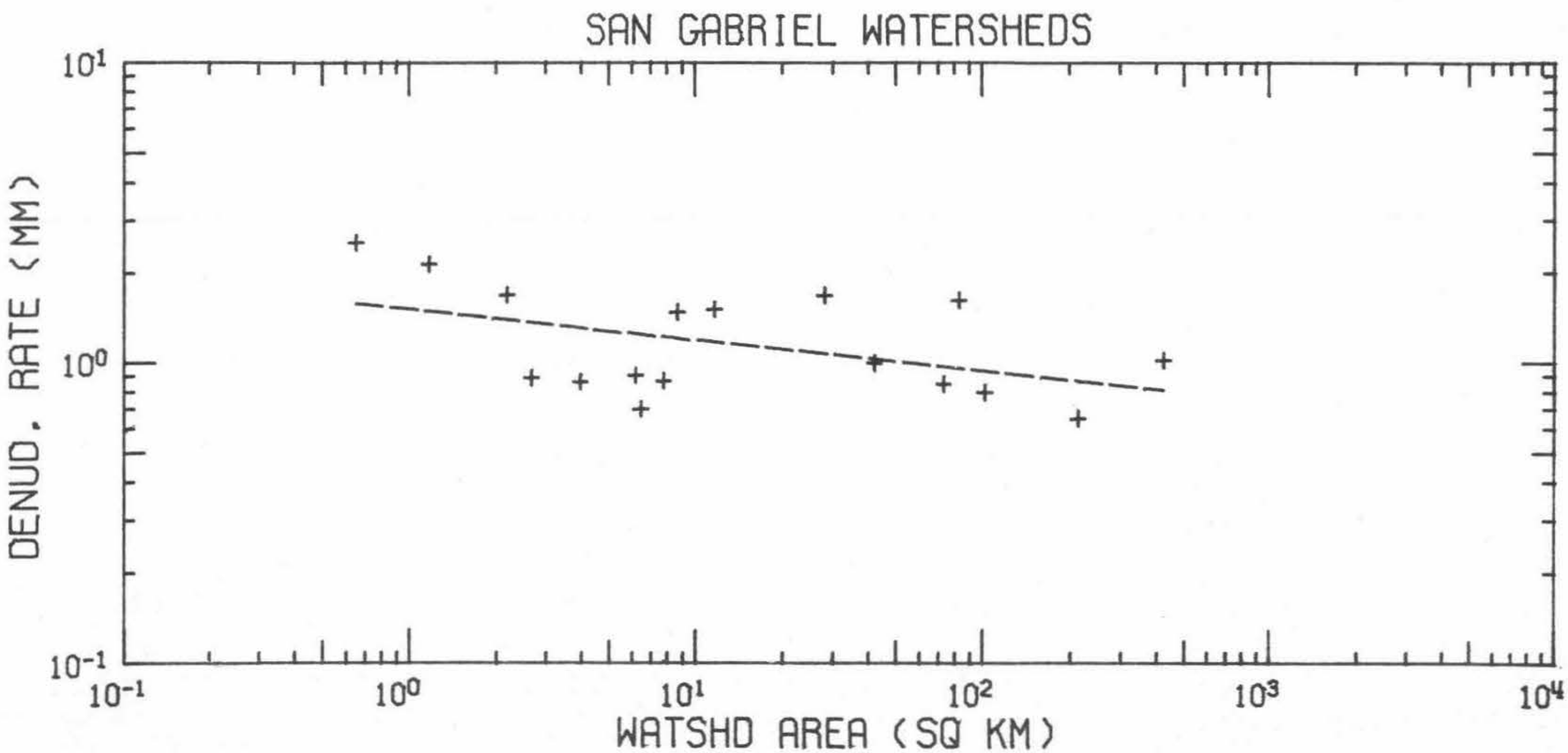


FIGURE 6

Mean Annual Denudation Dates (1939-1969) as a function of watershed area on 17 watersheds in the San Gabriel Mountains

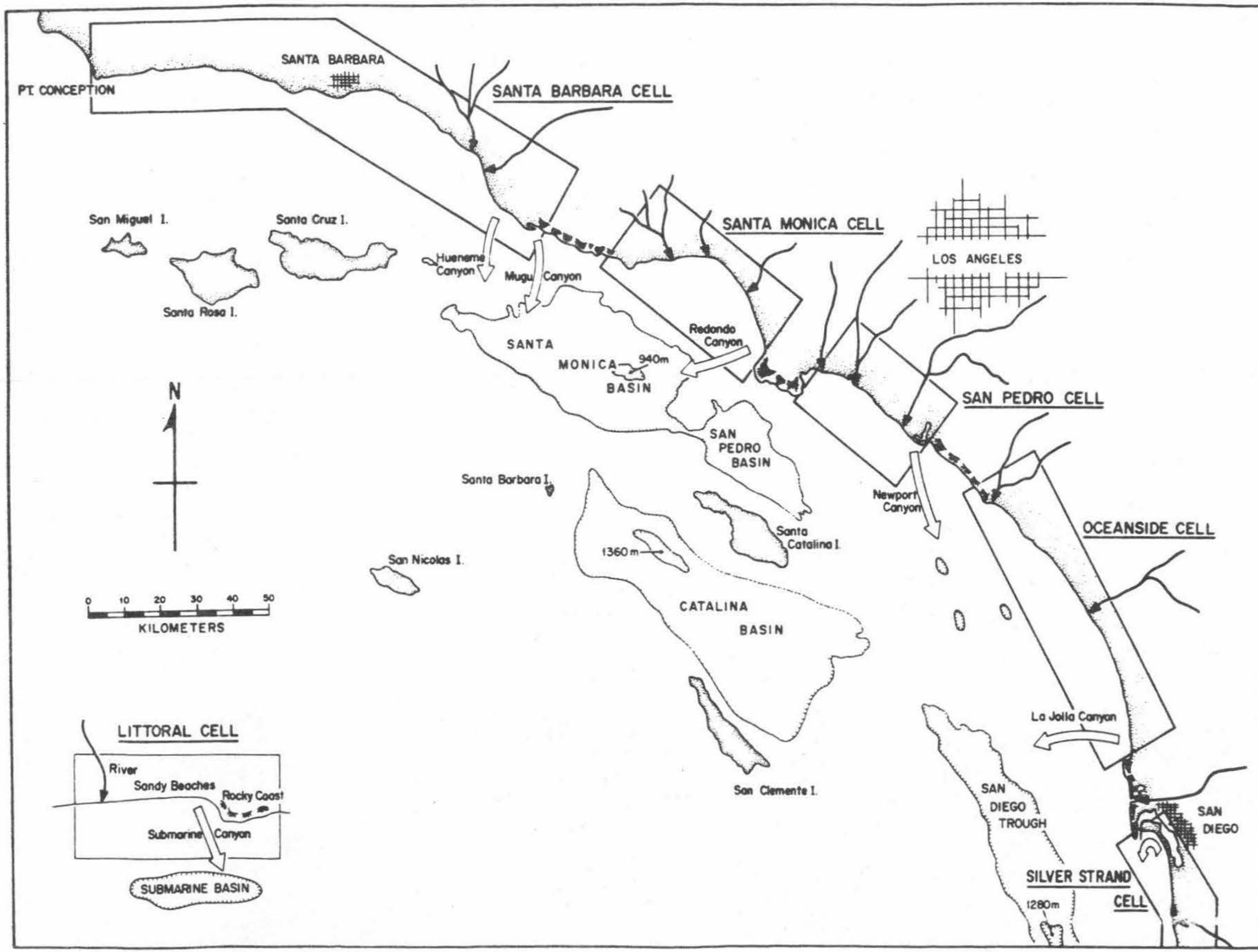


FIGURE 7. Littoral Cells in Southern California